TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

No. 258

NEW APPLICATION OF PRINCIPLE OF VARIABLE-CAMBER AIRFOIL.
(Lachassagne system)

By A. Toussaint.

From "Recherches et Inventions," July 21, 1922.

April, 1924.

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NEW APPLICATION OF PRINCIPLE OF VARIABLE-CAMBER AIRFOIL.*
(Lachassagne system)

By A. Toussaint.

In studying the application of his system of varying the camber of airfoil sections, Mr. Lachassagne has just obtained a series of airfoil sections whose polar envelope presents truly remarkable aerodynamic properties.

We gave in No. 39 (January 6, 1923) of this bulletin the description of the mechanism employed by Mr. Lachassagne for varying the camber. By starting with section 429 and applying to it variations in the camber compatible with the mechanism, the inventor successively obtained Nos. 430, 431, 432 and 438, as shown in Figure 1. In order to obtain them, Mr. Lachassagne made a rib with the initial section 429. This rib has the three usual parts.

1. A leading edge rigidly attached to a piece representing the front movable spar.

2. A central portion whose lower member is rigidly attached to pieces representing the movable front and rear spars and whose upper member, attached only to the front spar, slides on the upper member of the trailing edge.

* From "Recherches et Inventions," July 21, 1922, pp. 679-689. The C_y, C_x and C_m coefficients have been retained in the translation of this bulletin. They are convertible individually, however, to the absolute coefficients by dividing by 100. The equivalent scale of k_y and k_x in lb/sq.ft. - mi./hr. has been added.

3. A rear portion rigidly attached to the piece representing the movable rear spar.

By changing the form of this rib we can obtain the shapes corresponding to various cambers. Thus we obtained the airfoil sections shown in Figure 1. They correspond to different cambers of a Lachassagne variable-camber airfoil.

Wind tunnel tests.- Wooden models were made corresponding to these sections, for testing in the Eiffel wind tunnel. The airfoils thus tested were of rectangular plan with uniform cross-section and had the following dimensions: span 60 cm (23.62 in.); chord 10 cm (3.94 in.); aspect ratio 6; area 600 sq.cm (93.00 sq.in.).

The velocity of the air stream being 28 meters (91.86 feet) per second, the results obtained are proportional to a characteristic product Vl, equal to 2.8 sq.m (30.14 sq.ft.) per second.

Figures 2 and 3 give these results (Report 100B, Eiffel Laboratory). Figure 7 gives, on a larger scale, the polars, fineness ratios and the polar envelope which characterizes the aerodynamic properties of the deformable airfoil. The polar envelope is parallel to the induced parabola (or theoretical polar) throughout a considerable portion of its length. The corresponding airfoil-section drag varies from $C_{x_0} = 0.8$ to $C_{x_0} = 1$, which corresponds to the sole drag due to the friction of the air on the wing. The maximum fineness ratio is 24 for $C_y = 37$.

Remark.- We see, on Figure 7, that most of the polars intersect near $C_y \cong 92$ and $C_x = 5.6$. This peculiarity has already been observed in groups of airfoil sections corresponding to a variable camber airfoil. This was taken into account in plotting the polar envelope and the fineness curves.

Comparison with other airfoils.- It is interesting to compare this polar envelope with the polar envelopes of other known airfoils. Figure 8 gives this comparison and Figure 9 gives the different airfoil sections compared (Taken from Bulletin Technique of the S.T.Ae., March 12, 1923).

We have first compared the polar envelope (EL) for two airfoils, No. 1 A and No. 31 A, which have practically the same relative thickness as the variable-camber airfoil. The airfoil 1 A (Halbronn) has a slightly smaller C_x at lift coefficients below $C_y = 20$. The polar 1A coincides with the polar EL up to $C_y = 55$. Beyond this point it falls decidedly below EL. The wing 31A (Dewoitine) also has a slightly smaller C_x up to $C_y = 12$. Beyond this lift coefficient the polar 31A is slightly less than the polar EL.

This result was, moreover, to be anticipated, since the airfoils 1A and 31A with moderate camber cannot have, at the same time, the advantages of a small C_x and a large C_y.

The comparison is then continued with airfoils of greater camber, but relatively greater thickness.

a) Airfoil 73A (Göttingen 430 or Joukowski airfoil section),

$m/c = 13.8\%$ and $o/c = 5\%$, gives a polar parallel to EL up to about $C_y = 100$. The airfoil-section drag of 73A is, however, greater than for EL.

b) Airfoil 27A (Dewoitine), $m/c = 17\%$ and $o/c = 7.33\%$, is the one for which the polar remains parallel to EL the longest, with, however, a higher airfoil-section drag. This airfoil No. 27A is, moreover, considered by many engineers as the best of its class.

c) Airfoil 20A (Royer), $m/c = 17.4\%$ and $o/c = 8.85\%$, has a maximum C_y which exceeds that of EL, but its polar is considerably below EL for all lift coefficients below $C_y = 157$.

The result of this comparison is that, from the standpoint of the aerodynamic qualities C_x, C_y and fineness ratio C_y/C_x, a variable-camber airfoil, susceptible of including the sections which have given the polar EL, is superior to the best airfoils known with constant section.

The only airfoil of this type, capable of competing with the airfoil EL, would be airfoil 27A (Dewoitine). It is well, however, to remark that the latter airfoil has a much greater relative maximum thickness than EL (17% instead of 9.6%). It would, therefore, be better to compare airfoil 27A with a variable-camber airfoil whose constituent sections would also have a maximum thickness of $m/c = 17\%$. It is, in fact, known that the maximum lift coefficient increases, within certain limits, with m/c. It is also known that the increasing of m/c renders it possible to extend the upper limits of o/c, by retarding the appearance of the harmful phenomena due to the breaking away of the air filaments from the contour of the airfoil section. It is not unreasonable, therefore, to assume that, with a group of well plotted airfoil sections of 17% maximum relative thickness, we can obtain a polar envelope whose maximum C_y is above 160 and consequently preferable in this respect to 27A.

However that may be, the aerodynamic properties of the polar envelope of the new Lachassagne variable-camber airfoils appear susceptible of applications of practical importance to aviation.

Translated by
National Advisory Committee
for Aeronautics.

Fig. 1

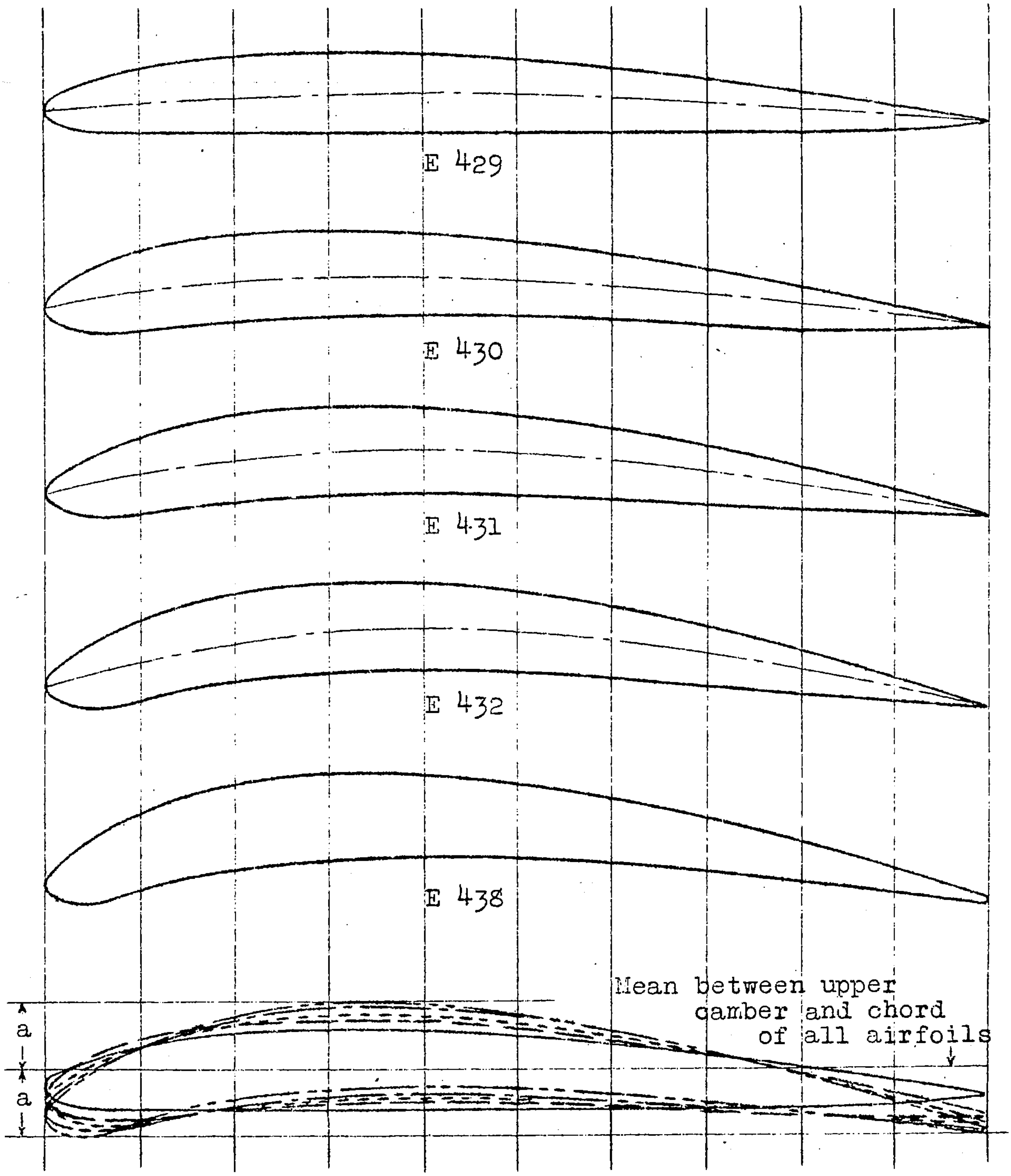
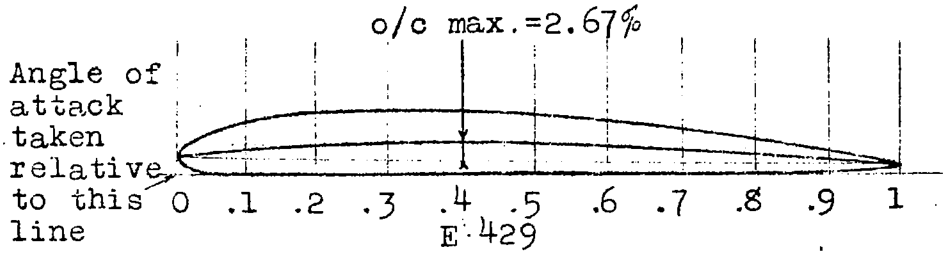

E 429
E 430
E 431
E 432
E 438
Mean between upper camber and chord of all airfoils
a
a

Fig. 1

Fig. 2



Angle of attack	-3°	0°	3°	6°	9°	12°	15°
100 C_y	-4.05	17.40	40.40	61.70	80.50	99.00	101.50
100 C_x	1.66	1.14	1.70	3.02	4.65	6.75	11.50
C_y/C_x		15.30	23.80	20.50	17.30	14.70	8.85
100 C_m		8.70	14.50	19.60	24.20	29.80	30.40

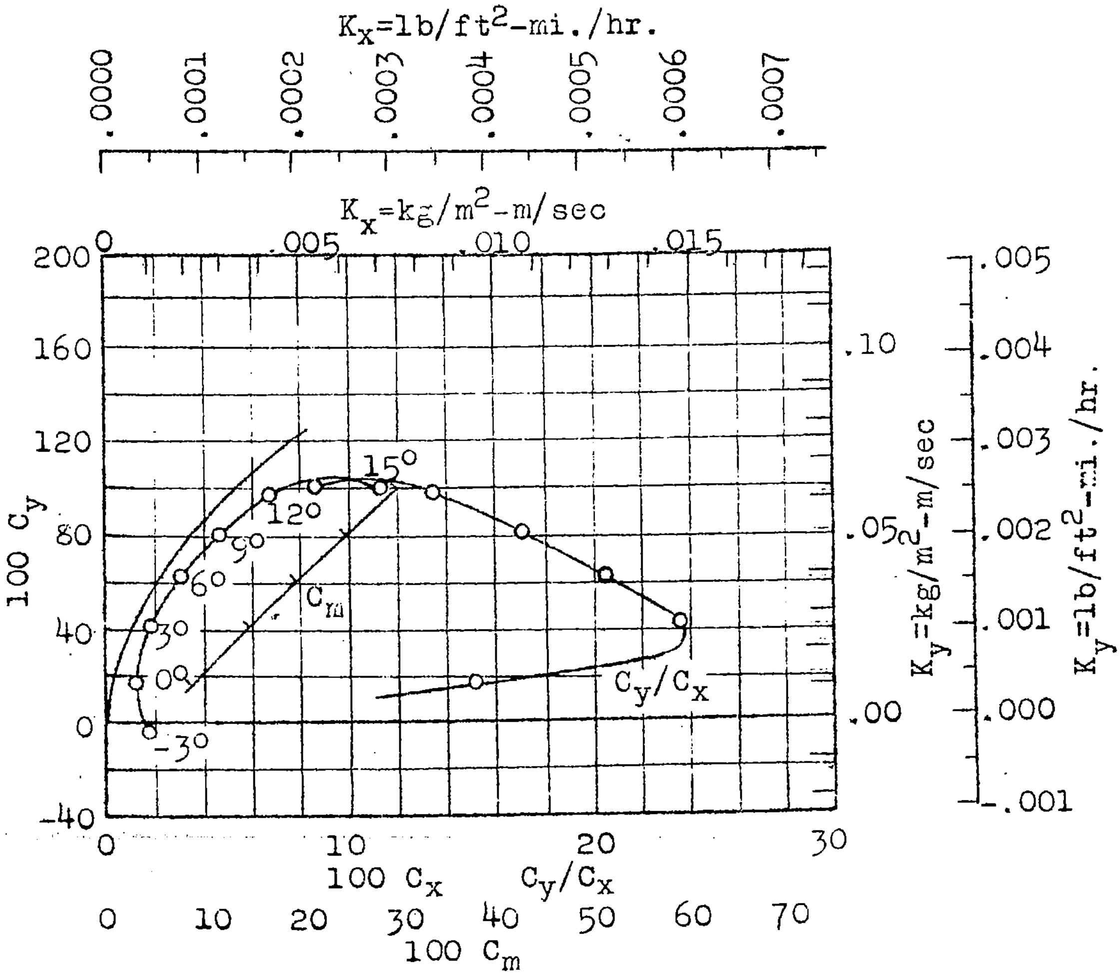
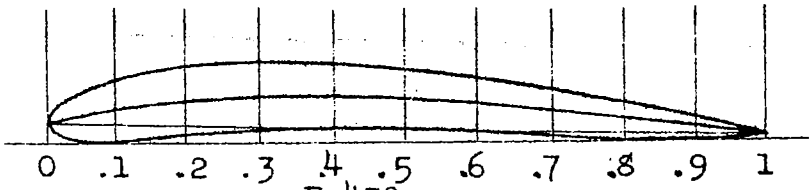


Fig. 2

Fig. 3

o/c max.=4.73%



E 430

Angle of attack	-6°	-1.5 -3°	1.5 0°	4.5 3°	7.5 6°	10.5 9°	13.5 12°	16.5 15°
100 C_y	-7.55	13.20	35.30	56.50	78.00	98.00	113.50	119.00
100 C_x	1.97	1.52	1.67	2.57	4.04	6.45	9.35	13.90
C_y/C_x		8.68	21.10	22.00	19.30	15.20	12.10	8.56
100 C_m			13.10	19.20	25.00	29.40	33.00	34.50

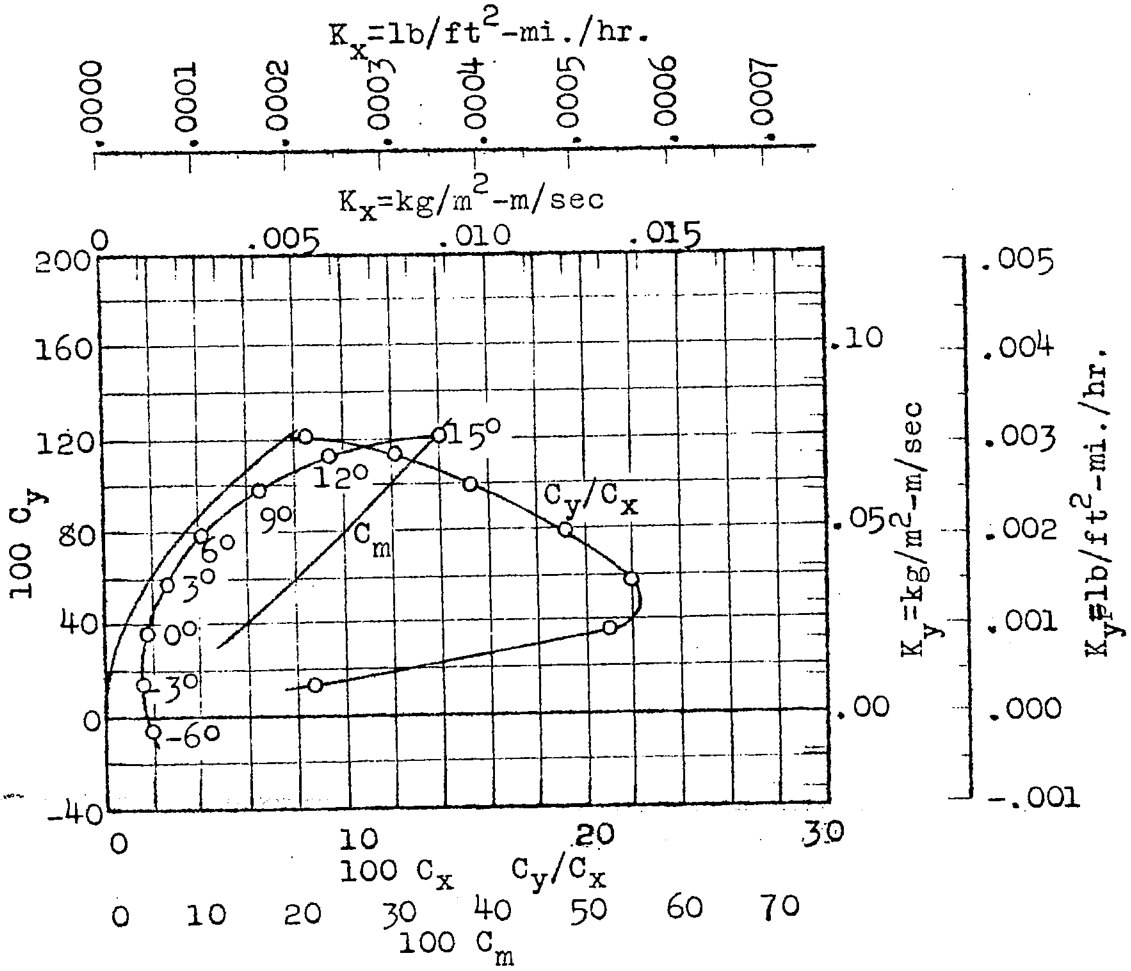
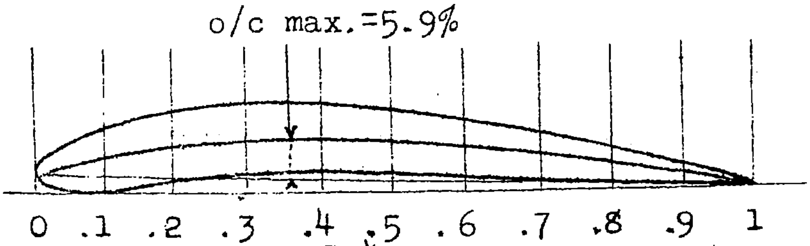


Fig. 3

Fig. 4



E 431

Angle of attack	-6°	-3°	0°	3°	6°	9°	12°	15°
		-1.7	1.3	4.3	7.3	10.3	13.3	16.3
100 C_y	5.34	26.70	49.70	71.00	90.00	110.00	123.00	127.00
100 C_x	1.68	1.95	2.33	3.70	5.48	7.90	10.35	14.40
C_y/C_x	3.18	13.70	21.70	19.20	16.60	13.90	11.90	8.82
100 C_m			21.90	27.80	33.30	36.70	39.30	38.20

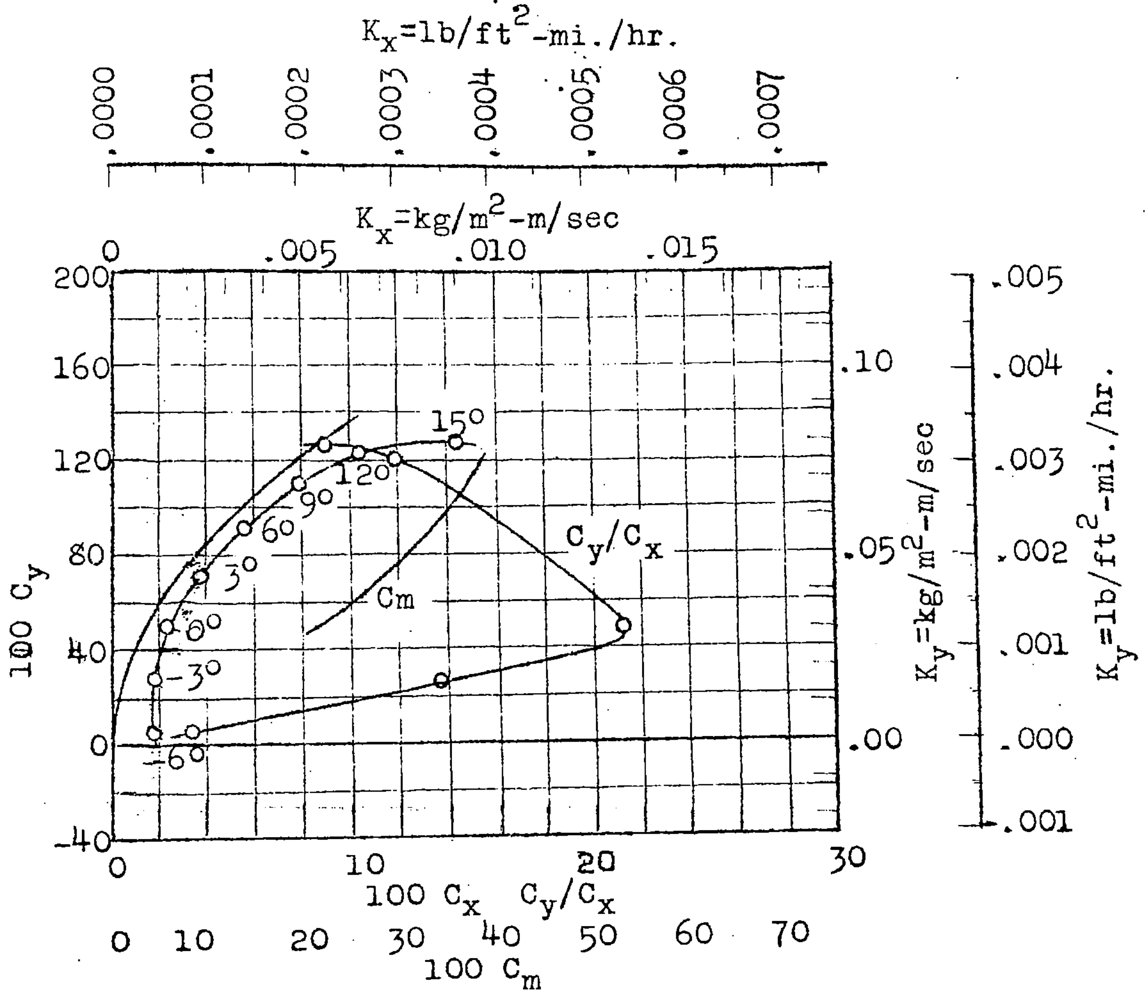
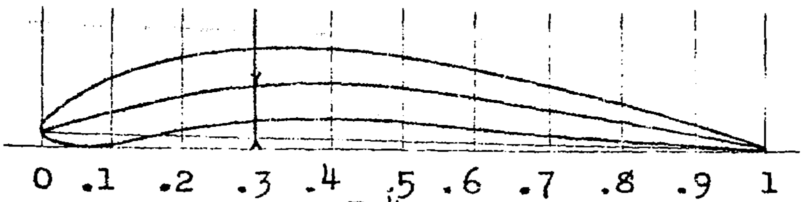


Fig. 4

Fig. 5

o/c max.=7.67%



E 432

Angle of attack	-6°	-3°	0°	3°	6°	9°	12°	15°
		-1.8	1.2	4.2	7.2	10.2	13.2	16.2
100 C_y	6.55	31.40	53.00	75.50	98.00	119.00	128.00	129.00
100 C_x	5.85	2.17	2.70	4.16	6.25	8.80	11.00	15.60
C_y/C_x	1.12	14.50	19.70	18.20	15.70	13.50	11.60	8.30
100 C_m		18.90	22.50	28.70	35.60	42.50	45.10	46.10

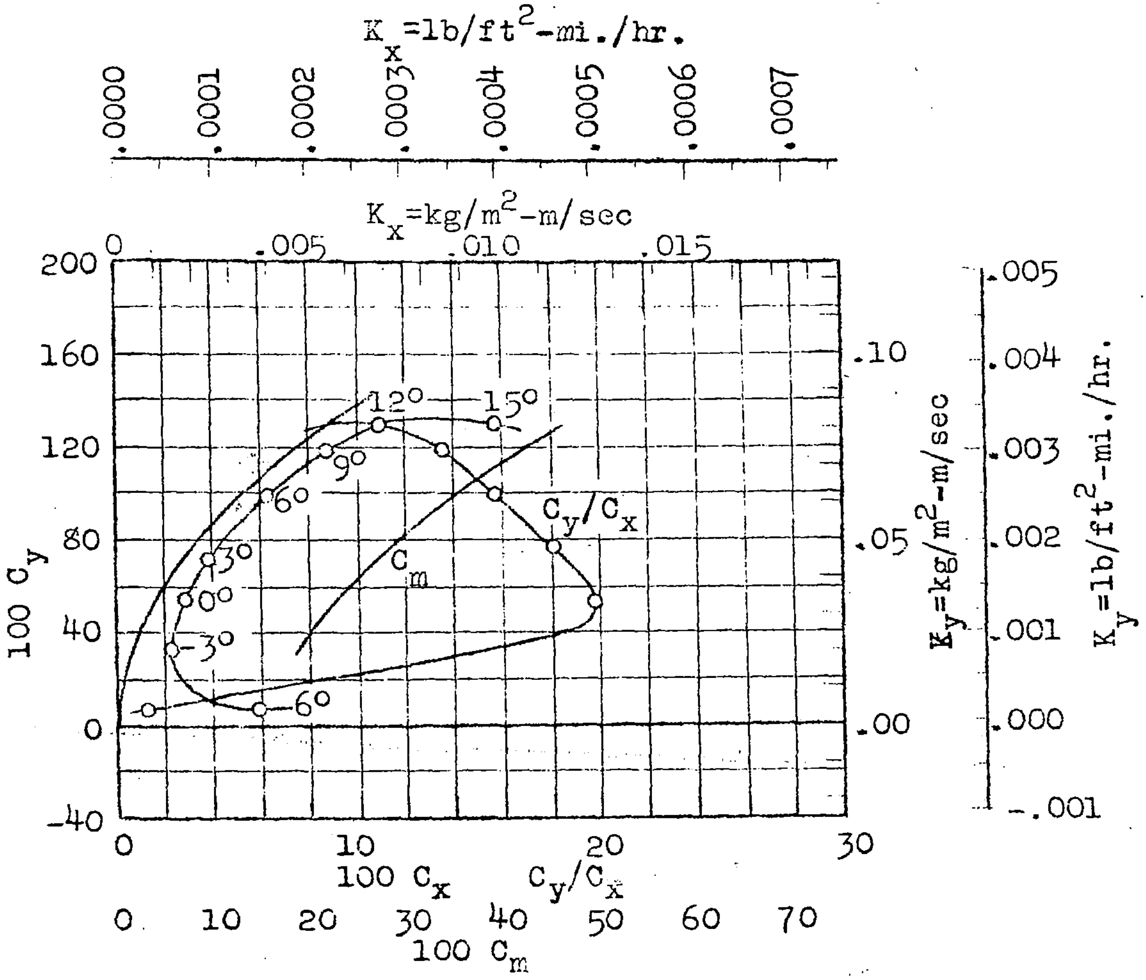
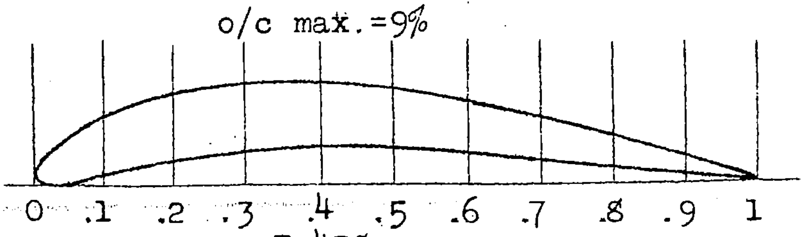


Fig. 5

Fig. 6



E 438

Wind velocity 28 m/sec (91.86 ft./sec.)

Angle of attack	-9°	-6°	-3°	0°	3°	6°	9°	12°	15°	18°
$100\ C_y$	-4.25	8.6	31.2	60.0	83.0	107.0	126.0	148.0	158.0	154.0
$100\ C_x$	9.90	7.30	5.42	3.75	4.95	7.05	9.75	13.80	17.80	22.90
C_y/C_x		1.18	5.75	16.0	16.8	15.2	12.95	10.70	8.85	6.72
$100\ C_m$		8.60	18.7	27.6	32.4	40.5	47.20	55.50	60.00	59.20

Wind velocity 15 m/sec (49.2 ft./sec.)

Angle of attack	-9°	-6°	-3°	0°	3°
$100\ C_y$	-3.25	9.2	33.4	56.8	82.0
$100\ C_x$	10.00	7.0	6.25	4.95	5.75
C_y/C_x		1.31	5.40	11.6	14.4
$100\ C_m$					

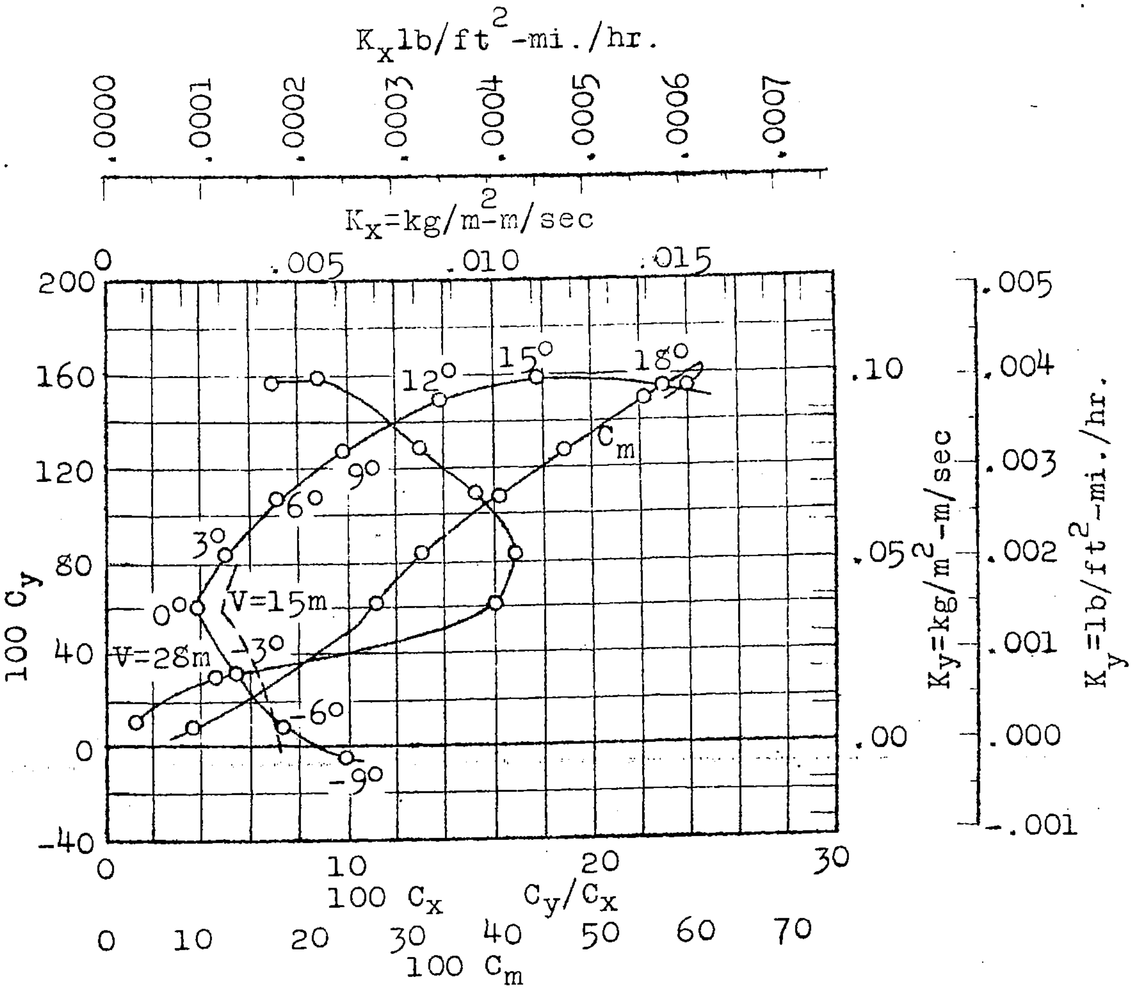


Fig. 6

Fig. 7

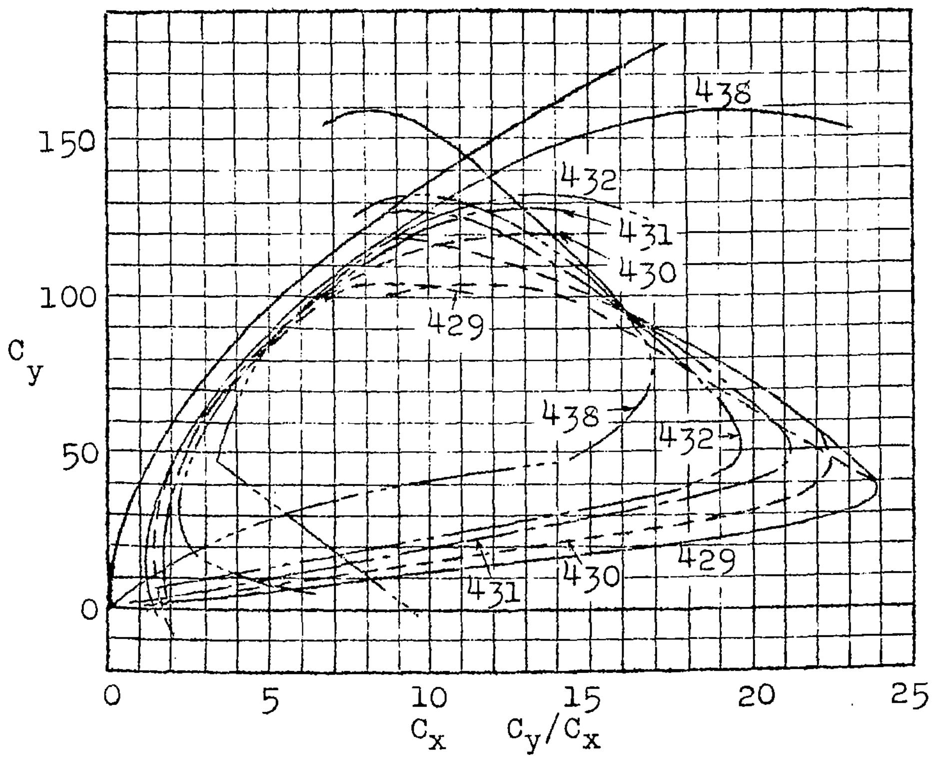


Fig. 7 Lachassagne variable-camber airfoils. Polars and fineness ratios of airfoils E 429, 430, 431, 432 & 438 (deformable or variable-camber.)

Fig. 8

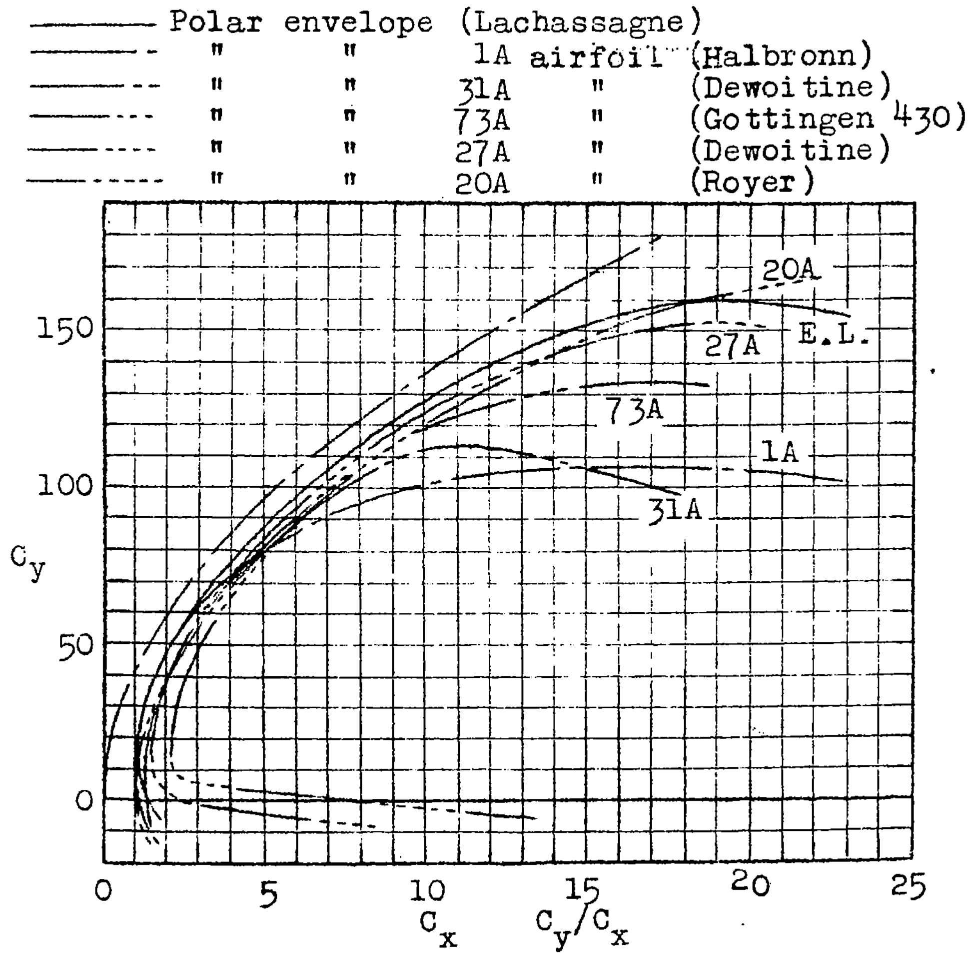
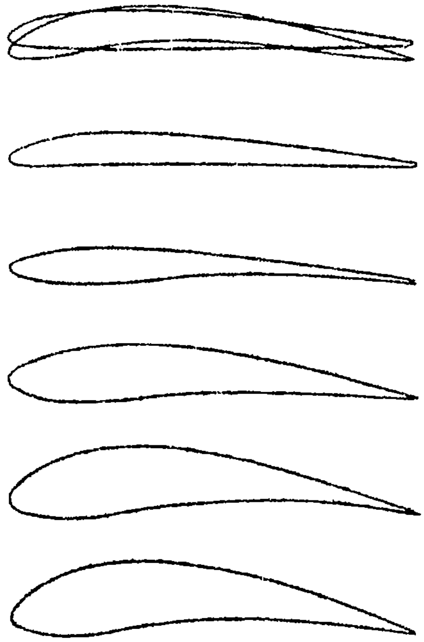


Fig. 8 Comparison of polar envelope of Lachassagne airfoil with the polars of other airfoils.

Fig. 9



Lachassagne variable camber airfoil. Max. thickness 9.6%.Camber variable,2.7 to 9%

Airfoil S.C.34 S.T. Aé,1A (Halbronn) m/c=8% o/c=3.33%

Airfoil S.C.95 S.T. Aé,31A (Dewoitine) m/c=9% o/c=2.80%

Airfoil S.C.56 S.T. Aé,73A (Göttingen 430) m/c=13.8% o/c=5%

Airfoil S.C.86 S.T. Aé,27A (Dewoitine) m/c=17% o/c=7.33%

Airfoil S.C.103 S.T. Aé,20A (Royer) m/c=17.5% o/c=8.85%

Fig. 9 Comparison of different airfoils with the Lachassagne deformable (or variable-camber) airfoil.